

Bell frog populations in New Zealand - good news or bad news?

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ABSTRACT

The aims of this paper are to describe the distribution and status of bell frog populations in New Zealand and to highlight the potential benefits these New Zealand populations have for collaborative studies. Bell frogs (*Litoria aurea* and *L. raniformis*) were introduced to New Zealand in the late 19th century. Over the past 100 years they have managed to spread to many parts of the entire country. Although their preferred habitat does not often overlap with that of the indigenous *Leiopelma* spp., their presence has raised many concerns within the local frog conservation community. The Native Frog Recovery Group (DOC, New Zealand) has the primary objective of securing populations of indigenous frogs (*Leiopelma* spp.) but in light of the high conservation status of bell frogs in Australia members of the group have often discussed their moral obligations regarding the conservation of introduced bell frogs in New Zealand. Although *Leiopelma* are totally protected species in New Zealand, bell frog tadpoles are commonly sold as pets and are regularly moved between North and South Islands. Advocacy for indigenous frogs relies heavily on previous exposure to the more charismatic and frequently encountered introduced bell frogs. The barriers associated with working on endangered and protected frogs in Australia could be avoided by conducting important conservation-related research on bell frogs in New Zealand. Several research projects (e.g. cryopreservation of female gametes, chytrid research) are briefly described that would provide data for more effective conservation of these species. In 2006 the New Zealand Frog Research Group was formed which provides the necessary infrastructure for such collaborative studies.

Key words: New Zealand, bellfrog, *Litoria raniformis*, *Litoria aurea*, distribution.

Introduction

Seven species of frogs in two genera, *Leiopelma* and *Litoria*, can be found in the wild in New Zealand. The four species of indigenous frogs (*Leiopelma archeyi*, *Leiopelma hamiltoni*, *Leiopelma hochstetteri* and *Leiopelma pakeka*) have all been listed in the top 100 EDGE Amphibians (www.edgeofexistence.org) and have been protected by law since 1921. Research or other manipulations of these frogs in the wild is controlled by the New Zealand Department of Conservation (DOC) and is well regulated. All species of *Leiopelma* have suffered severe declines since human habitation and now exist either on predator-free islands or in scattered isolated populations in a few areas on the North Island.

Although many species of frogs have been deliberately introduced to New Zealand since the late 1800s, only three have been successful in forming wild, self-sustaining populations. All three were introduced from Australia and belong to the genus *Litoria* (*Litoria aurea*, *Litoria ewingii* and *Litoria raniformis*). *Litoria ewingii* and *L. raniformis* have become quite widespread on both islands while *L. aurea* is confined to the warmer northern half of the North Island. As introduced species there are no regulations involved in capturing or handling *Litoria* frogs and they are frequently kept as pets by children. This has increased their distribution in New Zealand because they are frequently released into the wild once their owner has tired of them.

Fairly accurate records on the distribution of *Leiopelma* have been maintained by DOC and their range is quite well documented (Gill 1986; Pickard and Towns 1988) although several promising, remote and inaccessible areas have yet to be searched. Identifying the distribution of *Litoria* in New Zealand poses an interesting problem. The general public do not often report sightings of introduced frogs and often move them around the country indiscriminately. The New Zealand Frog Survey started to document their distribution and more recently data on introduced frogs have been incorporated into a DOC database and a hard copy of the Herpetological Atlas is currently in production.

The aims of this paper are to describe the distribution and status of bell frog populations in New Zealand and to highlight the potential benefits these New Zealand populations have for collaborative studies, some of which would be impractical in the reduced and protected frog populations in Australia.

History of introduced frogs in New Zealand

The introduction of frogs into New Zealand has been well documented in a single text entitled "The Naturalisation of Animals and Plants in New Zealand" by Thomson (1922) and the following information was obtained from that one source. Bell frogs (*Litoria aurea* and *L. raniformis*) were introduced to New Zealand in the late 19th century. The first documented introductions were conducted by the

Auckland Acclimatisation Society who introduced two frogs (*"Hyla aurea"*) in 1867 from Sydney mainly as a biological control agent against insects. In the following year they received several smaller consignments again from Sydney. These frogs reproduced successfully and were considered to be abundant all over the North Island by 1922.

The Canterbury Acclimatisation Society also received some *"Hyla aurea"* in 1867 from the Hobart Acclimatisation Society (presumably they were *L. raniformis*) and some tadpoles of the same species in 1868 from Mr Alport and Mr W L Hawkins.

The Southland Society received some spawn (possibly from Hobart) in 1868 that was hatched and distributed to various ponds on the Southland Plains, but they did not survive. A similar occurrence happened in Otago, where 60 frogs and tadpoles were obtained from Napier in 1888 and liberated, and again none survived. In the following years there were many inter-island translocations, as well as supplementations from Sydney, resulting in 'green' frogs being abundant all over the North Island and common throughout the South Island by 1922.

During the time of the introductions from Australia it appeared that the local people were largely unfamiliar with frogs (indigenous or introduced). Captain Gilbert Mair introduced bell frogs into Rotorua (North Island) in 1878, which were noted to be widespread in the district by 1916. Mair also commented that the local Maori people were unaware of frogs as they assumed these were some kind of new (demon-like) reptile.

Over the following 100 years bell frogs were regularly moved around the country as children's pets or in vain attempts to control mosquitoes.

Current distributions and the New Zealand Herpetological Atlas

With the growing interest in declining amphibian populations, coupled with the fact that the most recent frog distribution maps were 10 years out of date (Gill 1986), it was decided in 1997 to launch a national program (the New Zealand Frog Survey) to identify current distributions of the introduced frogs in New Zealand (Bishop 1999). This project was coordinated by P. Bishop (University of Otago) and B. Waldman (University of Canterbury) and through schools and the media they solicited reports on frog populations from the general public. These reports were usually accompanied by photographs and/or recordings in order to verify the accuracy of species identification. Unusual records were followed up by the coordinators.

After a slow start, hundreds of records began to accumulate and it was decided in 2000 to incorporate these records into a database called *Herpetofauna* administered by DOC. This database eventually evolved into the New Zealand Herpetological Atlas (NZHA), which launched the electronic draft version in 2006.

The NZHA project is managed by Benno Kappers (DOC, email: bkappers@doc.govt.nz) and the objectives are:

- To develop an up-to-date electronic and hard copy distribution atlas of the Amphibians and Reptiles of New Zealand

- For members of the public to be able to view and download herpetological species information and distribution maps from the www.doc.govt.nz environment
- To create wider awareness of the herpetological fauna of New Zealand and increased contribution of members of the public to the Herpetofauna database.

The NZHA has enabled the production of accurate and up-to-date distribution maps of all New Zealand frogs. The maps indicate that *L. aurea* is restricted to the 'warmer' parts of NZ (upper North Island) (Fig. 1). This species is found around Whareorino on the eastern side, all the way across to East Coast/Hawkes Bay area and northwards to the northern tip of Northland. They do not occur further south than 39°S. *Litoria raniformis* is widespread in New Zealand and occur sympatrically with *L. aurea* in many localities in the North Island (Fig. 2). There are several prolific populations in the South Island, with one notable, very large population in Central Otago where temperatures in winter often exceed minus 10°C with regular heavy frosts.

Both species of bell frogs appear to occur in large stable populations in which only a few dramatic declines have been reported. In 1999 the first incidence of chytridiomycosis was reported in a bell frog (*L. raniformis*) population in Christchurch (Bishop 2000; Waldman *et al.* 2001). During a field trip to an ephemeral pond in November and December 1999, 16 sick and dying frogs were discovered. All but one

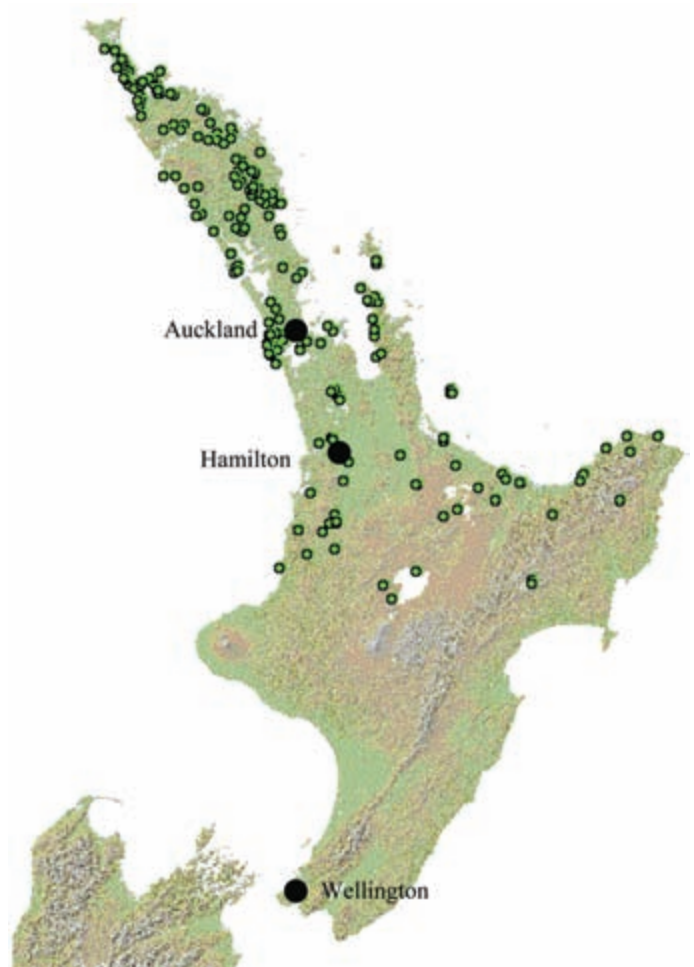


Figure 1. Distribution of *Litoria aurea* in New Zealand (Source: Herpetofauna 2006).

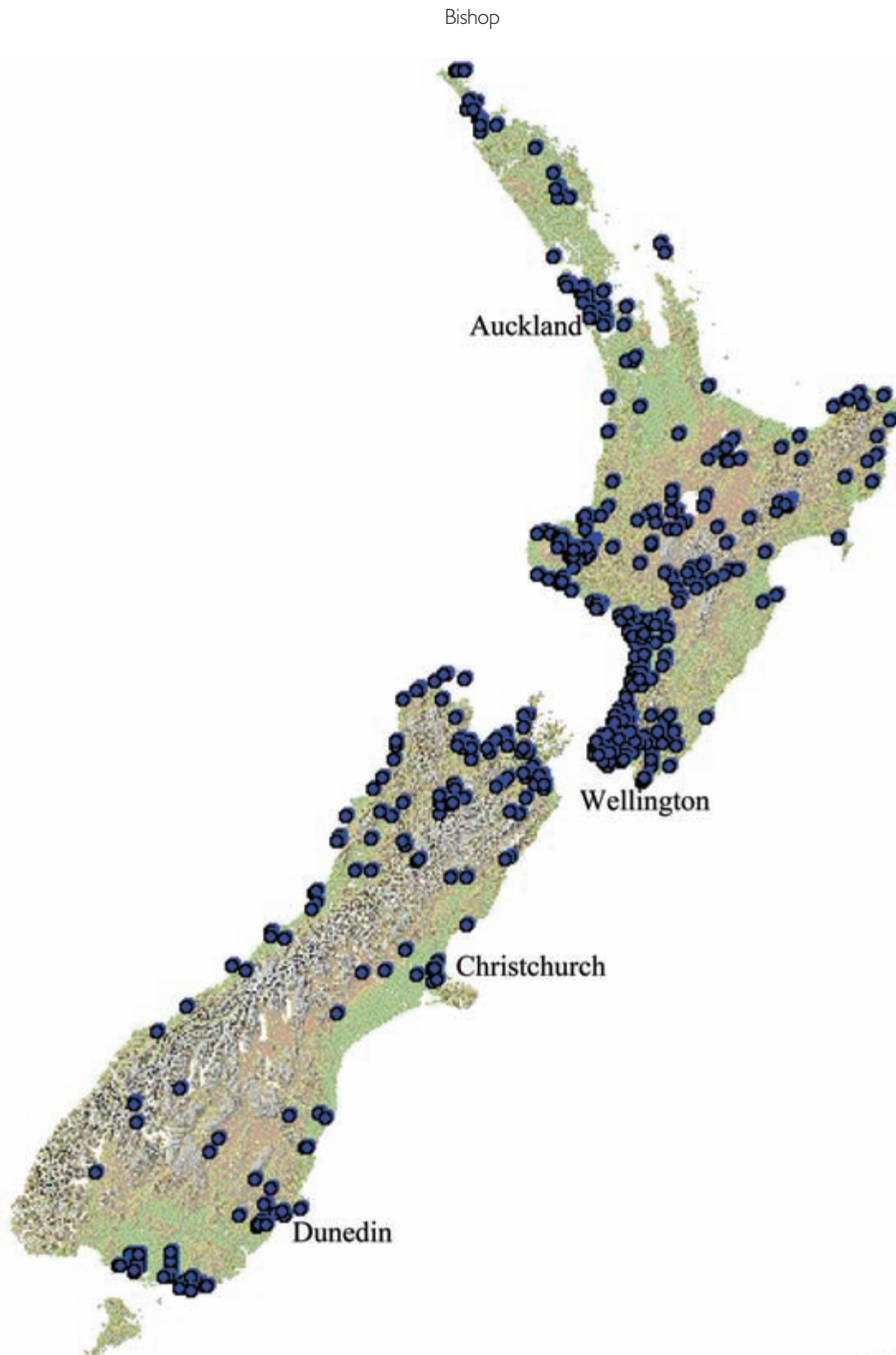


Figure 2. Distribution of *Litoria raniformis* in New Zealand (Source: Herpetofauna 2006).

of these sick frogs died within days and all displayed the typical symptoms of advanced chytridiomycosis (Waldman *et al.* 2001). After further investigations it appeared that many of the adult frogs had a certain amount of immunity to chytridiomycosis, although a high level of mortality was still observed in juvenile frogs (Waldman, unpublished data). Two years after the initial outbreak the population had started to recover and no signs of chytridiomycosis

were present (Waldman, pers. comm.). In 2006 there was an established breeding colony at the same pond with no evidence of sick or dying animals. *Batrachochytrium dendrobatidis* has now been identified in *Leiopelma archeyi* (North Island only), *Litoria raniformis* and *Litoria ewingii* on both islands. Its current distribution is being mapped by members of the New Zealand Frog Research Group (www.nzfrogs.org).

Besides acting as an alternative food source for introduced predators like hedgehogs and mustelids, the large charismatic bell frogs play an important role as glamorous advocates for public awareness and frog research in New Zealand. Historically it has always been a difficult task to stimulate public concern over the plight of indigenous *Leiopelma* frogs because they are cryptically colored and very rarely seen by the general public. New Zealand has recently started to celebrate an annual National Frog Week (Bishop 2006), which relies quite heavily on the use of bell frogs in workshops and displays around the country. Most of the knowledge of, and enthusiasm for, amphibians in New Zealand is a direct result of childhood exposure to bell frogs and their tadpoles.

The presence of bell frogs in New Zealand has not always been regarded as beneficial. During a study of *Leiopelma archeyi* in Whareorino, Thurley and Bell (1994) decided to investigate the stomach contents of *L. aurea* found at the same locality. To their surprise they discovered a pair of hind legs of *L. archeyi* and concluded that in this population the bell frogs have the potential to cause a lot of damage. This is the only known incidence of bell frogs preying on *Leiopelma*. As bell frogs do not generally occur in the same microhabitat as *Leiopelma*, they are unlikely to ever encounter one another even if they are broadly sympatric. Bell frogs are usually found in the lower altitude areas in close association with flooded wetlands or ponds while *Leiopelma* prefer the higher altitude indigenous forests and because most are terrestrial breeders they are often found a long way from any water bodies (Fig. 3). Another cause of concern is the potential bell frogs have as vectors of amphibian diseases. Following the chytridiomycosis outbreak in a bell frog population in 1999 there was a dramatic decline in the *L. archeyi* population on the Coromandel in 2001. This decline was suggested to have been caused by an outbreak of chytridiomycosis (Bell *et al.* 2004), and resulted in *L. archeyi* being re-categorised as Critically Endangered (IUCN, Conservation International, and NatureServe 2006). Although it is unknown what role (if any) bell frogs played in transmitting the fungal disease to *Leiopelma*, it can always be argued that the more abundant and mobile *Litoria* species act as reservoirs of a number of amphibian pathogens. As the bell frogs are introduced species in New Zealand they are only afforded very limited legal protection.

Legal protection

In New Zealand wildlife are protected under Section 3 of the Wildlife Act of New Zealand (1953), however, according to Schedule 5 of the Act "Amphibians - Green frog (*Hyla*), Whistling frog (*Hyla*)" are not protected. So it appears that all species of *Litoria* are covered by the 5th schedule and are therefore not protected in New Zealand. However in Section 56(1b) it states that "...no person shall export from New Zealand... any amphibian..." without the necessary permits.

Moreover, when Section 38(4d) of the Conservation Act of 1987 is considered it states that "...it is an offence to possess in any conservation area any animal...", consequently, bell frogs do become protected once they occur in a conservation area! Furthermore, in Section

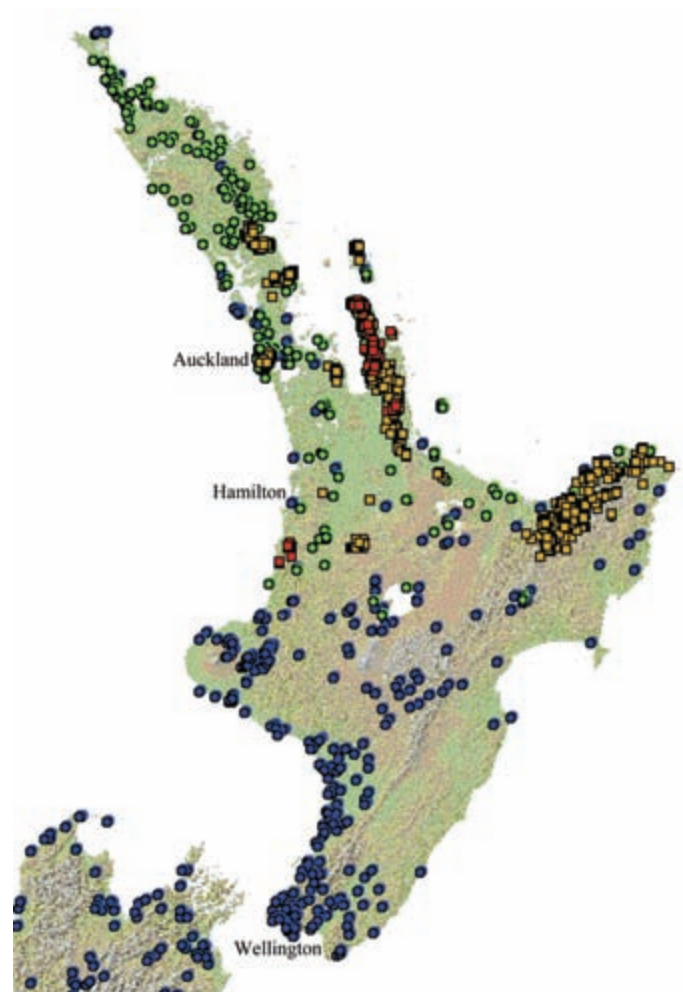


Figure 3. Distribution of *Litoria* and *Leiopelma* in the North Island and upper South Island of New Zealand (Source Herpetofauna 2006). (Green dots = *Litoria aurea*, blue dots = *Litoria raniformis*, yellow dots = *Leiopelma hochstetteri*, red dots = *Leiopelma archeyi*).

26ZM of the same Act, it states that "No person shall transfer live aquatic life or release live aquatic life into any freshwater..." and it defines aquatic life as "...any species of plant or animal life (except birds) that must, at any time of the life history of the species, inhabit freshwater; and includes any part of any such plant or animal...", so again, under this section of the Conservation Act the bell frogs have a limited amount of protection and should not be released into the wild (into "freshwater").

Future directions

New Zealand represents a unique opportunity for bell frog research. As these species only have a limited amount of protection in New Zealand, the only regulations to be met for conducting research would be those imposed by Animal Ethics Committees.

In several areas on the South Island (e.g. Central Otago) *L. raniformis* is plentiful, often reaching 'nuisance' proportions! In 2007 over 200 adult frogs were collected in a couple of nights from one location in Alexandra to be used for dissection at the University of Canterbury (P. Diver, pers. comm.).

There are many conservation-related questions that require invasive methodology to provide the appropriate answers. Amphibians as a group are renowned for species-specific differences in their responses to pathogens and other perturbations, thereby necessitating direct experimentation on the species in question, rather than extrapolating from those conducted on related species. With this in mind, New Zealand can provide the perfect 'laboratory' for invasive and sometimes terminal research on bell frogs. A few examples of important projects are outlined below:

Cryopreservation of female gametes and cell cultures

Gamete cryopreservation and freezing cell cultures have been identified as important tools in the conservation of endangered amphibians (Ryder 2007). To successfully develop these techniques harvesting of eggs and other tissues from many individuals would be necessary and this would be untenable in a declining population of endangered frogs. In New Zealand, cryopreservation of female gametes has only recently been successful and is largely limited to commercial aquaculture such as oysters (Tervit *et al.* 2005). However, samples of bell frog tissues could be easily harvested in New Zealand and transported to Australia for the development of species-specific techniques for bioresource banking.

Chytridiomycosis research

Amphibian chytrid fungus has been recorded in all three *Litoria* species found in New Zealand and has also been blamed for the demise of several populations (Waldman *et al.* 2001). In Australia, chytridiomycosis is also thought to be a significant factor in the decline of bell frogs (Obendorf 2005). With the extinction of 13 out of 31 *L. aurea* populations in the Sydney area in the last 10 years (White and Pyke 2008) it is becoming increasingly important to investigate the role of pathogens, species susceptibility and development of resistance, and how they are transmitted between individuals in susceptible species. Basic chytrid research is being conducted at the University of Otago (on *L. raniformis* and *L. ewingii*) with an emphasis on treating infected frogs in captivity and ways to prevent *Leiopelma* frogs from being infected by *Litoria* frogs. These experiments could easily be redeveloped to include *L. aurea* and to investigate other areas that are more pertinent to the conditions in Australia and bell frogs.

New Zealand as an 'amphibian ark' for bell frogs

In addition to providing frogs for invasive studies, New Zealand can act as an 'ark' for endangered bell frogs from Australia. Some scientists feel that it is morally irresponsible to host an endangered species from another country and to do nothing about it in the form of protection. In general, New Zealanders rank the conservation of animal species as a high priority and as bell frogs are thought to have an insignificant environmental impact on native fauna, then it would not be difficult to encourage the general public to act as guardians of introduced frogs. In New Zealand there are many public places and farm dams that contain good populations of bell frogs and these too could disappear in the future if people were not made aware of the significance of these frogs in Australia. It is conceivable that in the future reintroductions from New Zealand back to Australia could occur once the agents for decline have been identified and removed.

Basic biological research

There are many populations of bell frogs in New Zealand that are unique compared to their counterparts in Australia because they are composed of only one or two species of amphibians. In addition, there are several places where *L. aurea* occurs sympatrically with *L. raniformis* and suspected hybrids have been found (Pyke *et al.* 2002). It is vitally important to conduct as much basic biological research (breeding behaviour, mate choice, habitat usage, etc.) as we can on these species before they disappear from their native Australian habitat.

New Zealand Frog Research Group

Due to the increased awareness of declining frog populations in the world, more and more researchers in New Zealand are turning their efforts towards frog conservation. This necessitated the formation of a central network to promote efficient communication among frog researchers and to reduce the amount of overlapping studies, thereby saving limited resources. In 2007 a website was produced (www.nzfrogs.org) which describes all the frog research projects and provides the contact details of all the frog researchers in New Zealand. This website also acts as a public resource and provides important information on all species of amphibians in New Zealand. As the website describes the infrastructure of frog research in New Zealand it also acts as an important resource for anyone planning collaborative studies on bell frog biology in New Zealand.

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References

- Bell, B.D. 1982. New Zealand frogs. *Herpetofauna* 14:1–21.
- Bell, B.D., Carver, S., Mitchell, N.J. and Pledger, S. 2004. The recent decline of a New Zealand endemic: how and why did populations of Archey's frog *Leiopelma archeyi* crashed over 1996–2001? *Biological Conservation* 120, 189–199.
- Bishop, P.J. 1999. Declining frog populations in New Zealand – the New Zealand Frog Survey and possible future directions. *New Zealand Journal of Zoology* 26, 255–256.
- Bishop, P.J. 2000. Chytrid fungi identified from dying frogs in New Zealand. *Froglog* 39: 1–2.

- Bishop, P.J. 2006. World Amphibian Day. *Froglog* 73: 4.
- Gill, B.J. 1986. *Collins Handguide to the Frogs and Reptiles of New Zealand*. Collins, Auckland, N.Z.
- IUCN, Conservation International, and NatureServe. 2006. Global Amphibian Assessment. <www.globalamphibians.org>. Downloaded on 30 June 2006.
- Obendorf, D.L. 2005. *Application of field and diagnostic methods for chytridiomycosis in Tasmanian frogs*. Central North Field Naturalists Inc. Tasmania, Australia.
- Pickard, C.R. and Towns, D.R. 1988. *Atlas of the amphibians and reptiles of New Zealand*. Science and Research Directorate, Dept. of Conservation. Wellington, New Zealand. 59pp.
- Pyke, G.H., White, A.W., Bishop, P.J. and Waldman, B. 2002. Habitat-use by the Green and Golden Bell Frog *Litoria aurea* in Australia and New Zealand. *Australian Zoologist* 32(1), 12-31.
- Ryder, O.A. 2007. Bioresource Banking Efforts in Support of Amphibian Conservation. In: Gascon, C., Collins, J. P., Moore, R. D., Church, D. R., McKay, J. E., and Mendelson, J. R. III (eds). 2007. *Amphibian Conservation Action Plan*. IUCN/SSC Amphibian Specialist Group. Glan, Switzerland and Cambridge. UK. 64pp.
- Tervit, H.R., Adams, S.L., Roberts, R.D., McGowan, L.T., Pugh, P.A., Smith, J.E. and Janke, A.J. 2005. Successful cryopreservation of Pacific oyster (*Crassostrea gigas*) oocytes. *Cryobiology* 51 (2):142-51.
- Thomson, G.M. 1922. *The Naturalisation of Animals and Plants in New Zealand*. Cambridge University Press, UK.
- Thurley, T and Bell, B.D. 1994. Habitat distribution and predation on a western population of terrestrial *Leiopelma* (Anura: Leiopelmatidae) in the northern King Country, New Zealand. *New Zealand Journal of Zoology* 21: 431-436.
- Waldman, B., van de Wolfshaar, K.E., Klena, J.D., Andjic, V., Bishop, P.J. and Norman, R d B. 2001. Chytridiomycosis in New Zealand frogs. *Surveillance* 28(3): 9-11.
- White, A.W and Pyke, G.H. 2008. Green and Golden Bell Frogs in New South Wales: current status and future prospects. *Australian Zoologist* 34: 319-333.